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Fusion of polyethylene: Quality aspects regarding fusion joint preparation

Friedhelm Keller, Georg Fischer Wavin PLC, CH-Schaffhausen

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Fusion of polyethylene: Quality aspects regarding fusion joint preparation

Correct fusion joint preparation and the use of suitable tools has a large influence on the quality of the fusion produced. The oxide layer of the PE pipe must be removed in accordance with the specified guidelines in order to achieve a homogenous welded joint. Correct procedure throughout fusion preparation, as well as the tools and aids used, have a decisive influence on the quality produced.

Friedhelm Keller
Head of Product Management at
Georg Fischer Wavin PLC, Schaffhausen (CH);
Tel. +41(0)52/631-3534, E-Mail:
friedhelm.keller@piping.georgfischer.com

Requirements

All parties involved in a gas or water pipe net have to follow the regulations and the assembly instructions of the manufacturers so that the constructed PE piping net functions over the minimum period of 50 years under the defined operating conditions.

Thus we can assume that:

- The producers of the piping components
- The particular planner
- The operator
- The custom moulder
- Those responsible for instructing and training personnel

all pursue the same goal: to produce quality (**fig. 1**).

Annual investments of over 4 billion Euro in Germany for water and gas distribution can only become a long-term profitable investment if a 100% installation quality is assured.

To uphold the quality standard, the following rules apply to all parties involved:

- Basic factors of the planning
- The organisation of the planning
- The relevant quality standards and guidelines (DVGW, DVS, KRV, ISO, DIN-EN etc.)
- The assembly guidelines of the component manufacturer and
- The most up-to-date technologies

How can the quality of the manufacturers be assured?

Every product being offered on the market is usually controlled before being shipped. This quality control measure confirms primarily that the component's quality lies within the given tolerances.

Quality assurance goes significantly further than this, intervening as early as the ordering of the raw materials and continues right through to the distribution of the manufactured product.

The individual production stages are retraceable when a quality assurance system is implemented. These ideas are the basis of ISO 9000.

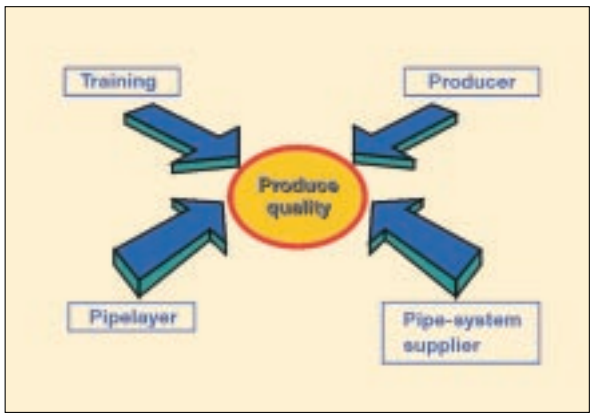

Fig. 1: Generation of quality

Before a product is placed on the market, product-release tests have to be fulfilled which are based on various standards. On top of that, these products are often subjected to further tests which have specific requirements. These specifications, also known as company standards, exceed the national and international requirements.

How can the quality of the pipe supply-system owners be assured?

The pipe supply-system owners may only assign work to certified pipe construction firms (e.g. Germany – DVGW GW 301) for pipe-laying work.

Accordingly, it has to be ensured that only (going by DVGW GW 330) qualified welders carry out the assigned work. These pipe construction firms have to avail of a welding supervision (according to DVGW GW 331) and this supervision has to be integrated into the company's quality cycle.

It appears to make sense that the client should supervise the building site. A qualified supervision can only be accomplished if the supervisor knows the process very well so that he can intervene if corrections have to be made.

The pipelayer has to supply the client with the welding information (according to DVGW GW 330). This information has to be controlled by the pipe supply company and stored accordingly. Such PE electronic welding data has been produced electronically for years and can be stored by the pipe-system suppliers in a data system. More recently, in addition to the welding information, extended pipe information can also be entered so that the prerequisites for a so-called electronic pipe sequence book exist.

Table 1: Wall-thickness reduction / chip thickness with dependence on nominal outer pipe diameter

Pipe outer diameter d [mm]	**Δ chip thickness s max.** [mm]
D 32 – 63	= 0,25
d 75 – 225	= 0,30
> d 225	= 0,35

How can the quality of the processing of the products be assured?

The pipelayer has to comply with the demands of the regulating body, making sure that the welding is done by qualified PE welders. Apart from knowledge about jointing techniques, these pipelayers must also be knowledgeable on national and international regulating bodies. Knowledge about assembly, installation and operating instructions should of course be without question.

The necessary installation equipment / aids as stated in the assembly instructions have to be available to the welder and have to be applied by him. Apart from making the work easier, the quality of the welding is positively affected and is usually faster and saves on costs.

Prelude: "He who makes high demands on a piping system is not allowed to make any retrenches concerning the product and, above all, the processing of this product".

PE materials

For the past few years, in addition to PE80 material, PE100 has been used in gas and water distribution. Cross-linked PE, so-called PE-X, has also been available on the market for some time. These materials, although they all belong to the PE material family, have different material characteristics. In comparison to PE80, PE100 can withstand higher operating pressures. Walls made of PE100 don't have to be as thickly constructed as walls made of PE80 to withstand the same pressure.

A further characteristic is that PE100 is harder than PE80. This directly influences the welding preparation process. This material characteristic has to be taken into consideration when processing.

Polyethylene is not UV resistant. For this reason, UV stabilisers are added i.e. additives which react / oxidise with the UV rays on the pipe surface. This oxidation layer protects the PE pipe from continuous UV damage.

The oxidation of the PE material is not visible and therefore cannot be seen by the welder. This oxide coat prevents a conclusive material bonding between the 2 components to be welded. It is or acts like a separating layer. Therefore, a fusion joint between an electro-fusion product and PE pipe requires a very clean, oxide-free surface. Nowadays, this important process is safeguarded by the use of rotating peeling devices. Apart from a substantial economical advantage achieved by time-saving work, these devices guarantee an exceptionally high processing quality.

Since the welder cannot retrace the length of time the pipe has been exposed to UV-rays, peeling must take place before welding even if no oxide layer is visible.

Fundamental, empirical values for the removal of the oxide layer are available. The removal of at least 0.2 mm pipe surface is necessary. Maximal values depend on the diameter of the pipe. If the nominal minimum specified outer diameter of the pipe is considered, then the wall thickness can be reduced according to **table 1**.

On the other hand, if the PE pipe is within the permissible plus tolerance range, the wall thickness reduction Δs can become larger. Here, the medium outer diameter of the pipe is decisive. It cannot, however fall short of the minimal permitted PE pipe diameter after peeling.

The values shown in table 2 are standard values; the details given by the fitting manufacturer are to be adhered to.

The fusion process begins by removing the oxide layer and is only completed after the cooling time. The welder has to supervise the welded joint during the entire process.

Tools for fusion seam preparation

Basically, there are two types of peeling tools available on the market:

- Peeler: chip removal with positive chip angle
- Scraper: chip removal with negative chip angle

In **picture 2**, various peelers and 1 scraper are shown.

A further, significant characteristic of scraper/peeler units is how they are fixated:

- Fixation of the unit only on the pipe end possible
- Fixation of the unit on the pipe end as well as the pipe segment possible

The types PT1E, PT2 and PT4 shown in picture two belong to the apparatus for processing pipe ends, the types PT3 and RS can be used for both pipe ends and pipe segments (necessary for saddle fusion) i.e. can be freely positioned and installed on the pipe.

The final significant characteristic makes a distinction between:

- Apparatus for one pipe nominal diameter (single tools) and
- Apparatus for several pipe nominal diameters (multi-tools).

PE1E, PT2 and PT3 belong to the "multi-tools", PT4 and RS are "single tools" i.e. only one apparatus per nominal pipe diameter can be used.

The rotary peeling tools are to be checked in regular intervals to ensure a trouble-free, optimum operation i.e. they are to be serviced. The removed diameter difference is to be measured, not the thickness of the removed chips. Depending on the frequency of use and function mode of the peeling equipment, these examinations should be carried out every 2 to 4 weeks by the fusion supervisors or the welder.

Table 2: Guideline figures for permissible nominal diameter of pipes for minimum chip removal

Dimension	**chip thickness** [mm]	**permissible PE pipe thickness*** [mm]
20	0,2	19,6
25	0,2	24,6
32	0,2	31,5
40	0,2	39,5
50	0,2	49,5
63	0,2	62,5
75	0,2	74,4
90	0,2	89,4
110	0,2	109,4
125	0,2	124,4
140	0,2	139,4
160	0,2	159,4
180	0,2	179,4
200	0,2	199,4
225	0,2	224,4
250	0,2	249,3
280	0,2	279,3
315	0,2	314,3
355	0,2	354,3
400	0,2	399,3
450	0,2	449,3
500	0,2	499,3

* The information relates to the nominal PE pipe diameter without + tolerance. Conclusion: If the middle PE pipe outer diameter is at the upper tolerance limit, the pipe striping can be removed to the average reduced permitted PE pipe diameter by peeling. In this case, the wall thickness reduction can be larger.

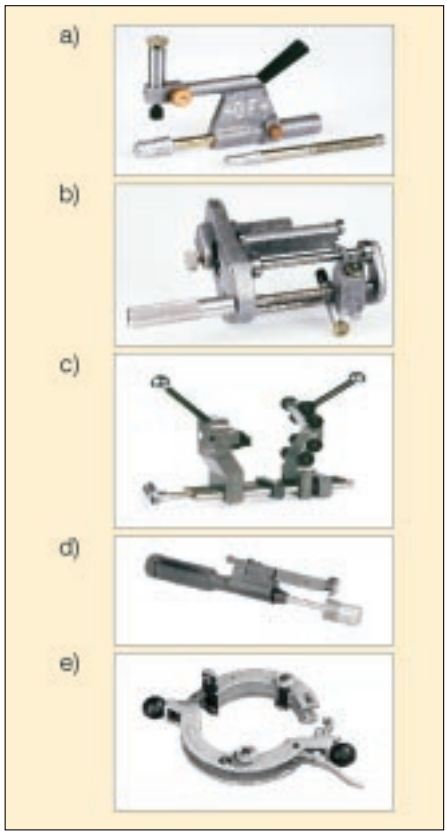

Fig. 2: Peeler types: a) Type PT1E, b) PT2, c) PT3, d) PT4; example of a scraper: e)Type RS

Pipe laying aids

During fusion, the two components to be joined are in a semi-liquid state to one another. Throughout the process, the components have to be kept in a tension-free condition. This tension-free state is safeguarded by clamps which in certain cases can be an integral part of the fitting. Other methods practised on building sites cannot be recommended. For the sake of a good pipe laying quality, these practises should be avoided (**fig. 3**).

Other tools and devices available to ensure an efficient and professional installation of pipe net components are depicted in **picture 4**.

Fusion parameters

The main fusion parameters dictate the fusion process and affect not only the fusion joint preparation but also the fusion joint solidity. These parameters are:

- Fusion pressure
- Fusion time
- Fusion temperature and
- Fusion joint preparation.

Fusion pressure

The fusion pressure is mainly determined by the reaction between the peeled PE pipe (reduced, peeled PE outer diameter) and the inner diameter of the PE fitting. The design as well as the electrical and energetic concept of the fitting have also a large influence on the fusion pressure.

If too much PE material is removed from the PE pipe surface during peeling, it negatively affects the fusion pressure and thereupon the fusion joint quality. It is of absolute importance that the oxide layer is removed (at least 0.2 mm). It is clear to see here that a limitation of the maximum pipe wall thickness reduction has to be set in conjunction with the nominal pipe outer diameter and its accompanying plus tolerances (see table 2).

The new PE100 and PE-Xa materials display a high degree of hardness so that the oxide layer cannot be removed by a scraper blade (manual scraper) with reproducible quality. Numerous tests carried out on electro-fusion joints with pipes made of PE80, PE100 and PE-Xa have shown that a clearly better homogeneity and integrity of the fusion joint can be achieved by the use of rotary peeling tools.

According to DVS 2207, part 1, appendix 1, only mechanical preparation with rotating peeling tools is recommended when using PE-Xa. While rotary peeling tools are cost-saving, efficient and above all make reproducible results possible, the scraping process using hand scrapers essentially depends on the experience of the fitter.

Fusion time and fusion pressure

The fusion time and the resulting temperature are determined by the fitting manufacturer and, by means of a bar-code or magnet card, this information is made available to the fitter. This information is read in by a light pen or by the magnetic card reader of the electrical welding machine. The welding machine then carries out an automatic temperature compensation so that the various surrounding temperatures are balanced.

Preparation of welding joint

Preparation of work area

The welder should create enough space around the PE pipe so that he can carry out the necessary fusion joint preparations without significant hindrance. Coarse dirt should be removed from the pipe joint with a cloth or paper towel (**fig. 5a**). The cleaning of the jointing area is necessary so as to prevent an unnecessary erosion of the tools.

Cutting the PE pipe into lengths

The PE pipe is cut into lengths at right angles by a coil pipe cutter, a fine-tooth saw or a pipe cutter. Slanted or crookedly-cut pipes are to be avoided. If, however, pipes are cut at a slant angle or straight-cut pipes are not installed centrally, the fusion pressure cannot be correctly built up and plasticized PE material escapes into the pipe wall area, which has a negative effect on the fusion joint quality.

Peeling the PE pipe

The fusion area on the pipe is peeled with a rotating peeling unit beyond the required insertion depth or saddle width (**fig. 5b**).

Fig. 3: The use of holders versus conventional, time-consuming methods, which should be avoided in order to achieve good installation quality

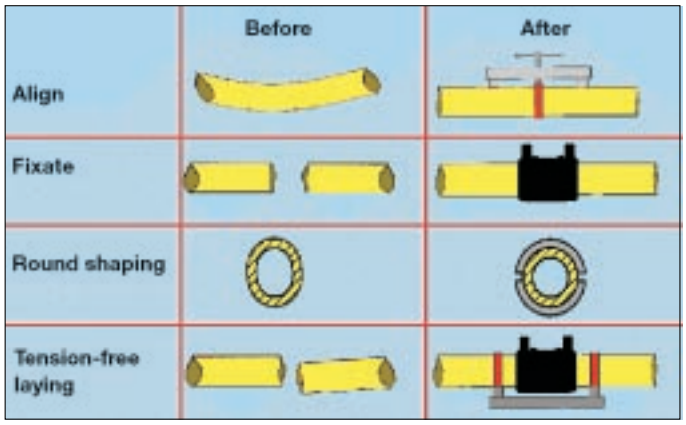

Fig. 4:
Tools and installation aids used for the various tasks in installation

Cleaning

Only the peeled area of the PE pipe is cleaned with a special PE pipe cleanser (Tangit PE cleanser) and absorbent non-fibrous paper. (**fig. 5c**). It is important that that the right towel, the right cleanser and the right amount of cleanser are used. If more than the peeled surface is cleaned, the danger arises that dirt from the non-peeled areas be transferred to the peeled area by the cloth or the paper towel. Such a contamination leads to a decrease in the jointing quality.

Marking the insertion depth

The marking of the insertion depth of fusion fittings should take place after the cleaning. Extensive marking before peeling should be avoided, as only a small part of the indicated area will be peeled (**fig. 5d**). There is a danger that the pen marking will be removed when cleaning (beyond the peeled area) and transferred over to the fusion area. This can be avoided by first marking when the cleaning process has been completed.

Installation of Electrofusion product

The electrofusion products are to be installed according to the manufacturer's instructions (assembly instructions) (**fig. 5e**). Contamination of the fusion area is to be avoided during the installation. Therefore, the PE fittings are only now removed from the PE bags. In doing so, the contamination of the fusion surfaces is avoided. The PE fitting may not be mounted on the PE pipe under tension and the pipe has to be protected against positional changes by means of a clamp throughout the fusion, until completion of the cooling phase.

Fusion

The Electro fusion product mounted on the PE pipe is to be fused according to the operating instructions of the Electro fusion machines and assembly instructions of the Electro fusion product (**fig. 5F**). The fusion process is only complete after the cooling phase.

If these regulations are adhered to, a significant contribution on behalf of the pipelayer to increase the fusion joint quality has been achieved.

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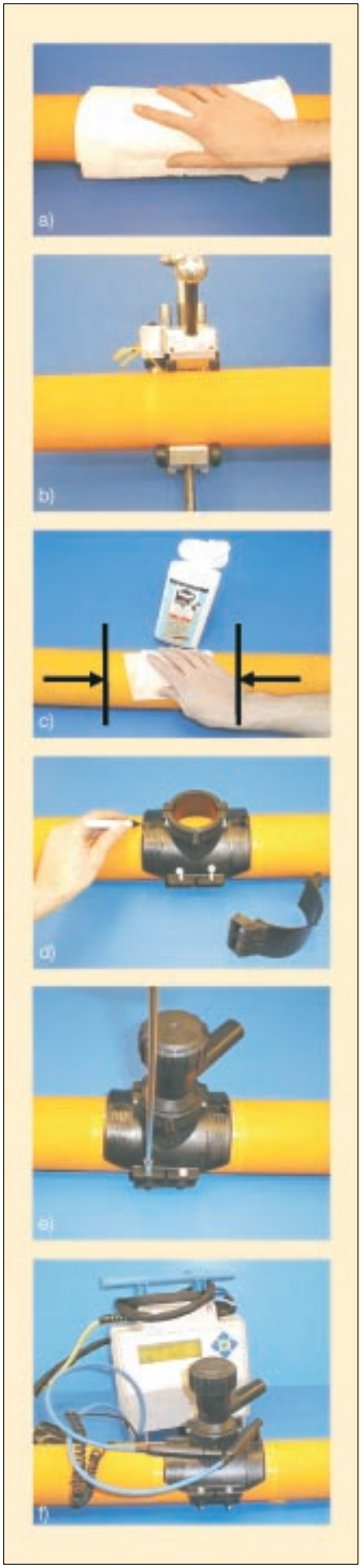

Fig. 5:
Welding of a saddle-type valve: a) Preparation of the working area, b) Peeling of the PE pipe, c) Cleaning, d) Marking of insertion depth, e) Mounting of electro-welding product, f) Welding

GEORG FISCHER +GF+

A Georg Fischer Rohrleitungssysteme GmbH, Sandgasse 16, 3130 Herzogenburg, Tel. +43(0)2782/8 56 43-0, Fax +43(0)2782/8 51 56, e-mail: office@georgfischer.at
AUS George Fischer Pty. Ltd., 4 Jacks Road, South Oakleigh, Victoria 3167, Tel. +61(0)3/95 63 88 99, Fax +61(0)3/95 63 89 66, e-mail: sales@georgefischer.com.au
B/L Georg Fischer NV/SA, Digue du Canal 109-111 – Vaartdijk 109-111, 1070 Bruxelles/Brüssel, Tél. +32(0)2/556 40 20, Fax +32(0)2/524 34 26
e-mail: info.be@be.piping.georgfischer.com
BR George Fischer Ltda., Av. das Nações Unidas 21689, CEP 04795-100 São Paulo, SP, Brasil, Tel. +55 11 247 1311, Fax +55 11 247 6009
Internet: http://www.br.piping.georgefischer.com
CH Georg Fischer Rohrleitungssysteme (Schweiz) AG, Amsler-Laffon-Strasse 1, Postfach, 8201 Schaffhausen, Tel. +41(0)52/631 30 26, Fax +41(0)52/631 28 97
e-mail: info@rohrleitungssysteme.georgfischer.ch
Georg Fischer Wavin AG, Industriestrasse 24, 4553 Subingen, Tel. +41(0)32/613 21 11, Fax +41(0)32/614 31 74
CHINA Georg Fischer Piping Systems Ltd. Shanghai, No. 218 Kang Qiao Dong Rd., Shanghai 201319, Tel. +86(0)21/58 13 33 33, Fax +86(0)21/58 13 33 66
e-mail: gfsro@public.shanghai.cngb.com
D Georg Fischer GmbH, Daimlerstraße 6, 73095 Albershausen, Tel. +49(0)7161/302-0, Fax +49(0)7161/302 259
e-mail: info@georgfischer.de, Internet: http://www.rls.georgfischer.de
DK/IS Georg Fischer A/S, Klintehøj Vænge 17, 3460 Birkerød, Tel. +45 45 81 19 75, Fax +45 45 81 16 22
E Georg Fischer S.A., Sistemas de tuberías para la industria, Alcalá, 85, 2°, 28009 Madrid, Tel. +34(0)91/781 98 90, Fax +34(0)91/426 08 23
e-mail: info@georgfischer.es
F George Fischer S.A., 105–113, rue Charles Michels, 93208 Saint-Denis Cedex 1, Tél. +33(0)1/49 22 13 41, Fax +33(0)1/49 22 13 00, e-mail: info@georgefischer.fr
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I Georg Fischer S.p.A., Via Sondrio 1, 20063 Cernusco S/N (MI), Tel. +3902/92 18 61, Fax +3902/92 14 07 85, e-mail: office@piping.georgfischer.it
Georg Fischer Pfci Srl, Via dell'Artigianato, 31/33 – Loc. Broglie – 37019 Peschiera del Garda (VR)., Tel. +39(0)45 640 14 18, Fax +39(0)45 640 14 09
e-mail: pfci@alupex.com
ALPRENE S.r.l., Via Bonazzi, 32, Castel Maggiore, 40013 Bologna, Tel. +39051/63 24 211, Fax +39051/63 24 213, e-mail: info@alprene.it
N Georg Fischer AS, Rudsletta 97, 1351 Rud, Tel. +47(0)671 717 40, Fax +47(0)671 392 92
NL Georg Fischer N.V., Lange Veenteweg 19, Postbus 35, 8160 AA Epe, Tel. +31(0)578/678222, Fax +31(0)578/621768
e-mail: info.vgnl@nl.piping.georgfischer.com, Internet: http://www.georgfischer.nl
Georg Fischer WAGA N.V., Lange Veenteweg 19, Postbus 290, 8160 AG Epe, Tel. +31(0)578/678378, Fax +31(0)578/620848
e-mail: info@waga.georgfischer.com, Internet: http://www.waga.nl
PL Georg Fischer Sp. z o.o., ul. Radiowa 1A, 01-485 Warszawa, Tel. +48(0)22/638 91 39, Fax +48(0)22/638 00 94
S/FIN Georg Fischer AB, Box 113, 12523 Älvsjö-Stockholm, Tel. +46(0)8/506 77 500, Fax +46(0)8/749 23 70, e-mail: info@georgfischer.se, Internet: http://www.georgfischer.se
SGP George Fischer Pte. Ltd., 15 Kaki Bukit Road 2, KB Warehouse Complex, 417 845 Singapore/Singapore, Tel. +65(0)7/47 06 11, Fax +65(0)7/47 05 77
e-mail: info@georgfischer.com.sg
USA George Fischer Inc., 2882 Dow Avenue, Tustin, CA 92780-7285, Tel. +1(0)714/731 88 00, Toll Free 800/854 40 90, Fax +1(0)714/731 46 88
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e-mail: info@piping.georgfischer.com, Internet: http://www.piping.georgfischer.com

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